



LPR 7123.1 B
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Langley Research Center

LaRC Systems Engineering Processes and Requirements

National Aeronautics and Space Administration

DOCUMENT HISTORY LOG

Document Revision	Effective Date	Description
A	July 20, 2010	Baseline
A-2	June 12, 2012	Adds Appendix G
A-3	April 25, 2014	Revises Appendix G
B	May 28, 2015	<ul style="list-style-type: none">• Updates to be compliant with NPR 7123.1B• Revises Section 2.3 to address NPR 7123.1B Compliance Matrix H.1 and H.2• Replaces Appendix E with completed NPR 7123.1B H.1 Compliance Matrix• Changes Project "Class" to Project "Type" to be consistent with LPR 7120.5.• Updates Table 1-1 Revises Appendix G

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PREFACE

P.1 PURPOSE

P.1.1 This Langley Procedural Requirements (LPR) document implements the Agency Systems Engineering Management requirements documented in NASA Procedural Requirements (NPR) 7123.1B Appendix C. These processes focus on defining stakeholder expectations and implementing a systematic approach for satisfying those expectations. The processes are extracted from industry, national, international, and Agency standards. These processes provide the best typical practices currently available.

P.2 APPLICABILITY

P.2.1 This LPR applies to the personnel, programs, and projects at LaRC, including contractors to the extent specified in their respective contracts or agreements. ("Contractors," for purposes of this paragraph, include contractors, grantees, Cooperative Agreement recipients, Space Act Agreement partners, or other agreement parties.)

P.2.2 This LPR applies to all Programs and Projects conducted by LaRC that are governed by NPR 7120.5, *NASA Spaceflight Program and Project Management Requirements*. This LPR also applies to all Institutional Infrastructure Programs and Projects conducted by LaRC (with the exception of environmental compliance and restoration activities), that are governed by NPR 7120.7, *NASA Information Technology and Institutional Infrastructure Program and Project Management Requirements*. In addition, this LPR applies to Technology Development Programs and Projects conducted by LaRC that are governed by NPR 7120.8, *NASA Research and Technology Program and Project Management Requirements*.

P.3 AUTHORITY

National Aeronautics and Space Act, as amended, 51 U.S.C. § 20113(a).

P.4 APPLICABLE DOCUMENTS AND FORMS

- a. NPR 7120.5, NASA Space Flight Program and Project Management Requirements
- b. NPR 7120.7, NASA Information Technology and Institutional Infrastructure Program and Project Management Requirements
- c. NPR 7120.8, NASA Research and Technology Program and Project Management Requirements
- d. NPR 7123.1, NASA Systems Engineering Processes and Requirements
- e. NPR 7150.2, NASA Software Engineering Requirements
- f. NPR 8705.4, Risk Classification for NASA Payloads

- g. LAPD 7000.2, Review Program for Langley Research Center (LaRC) Facility Projects
- h. LPR 1440.7, Langley Research Center (LaRC) Records Management Procedural Requirements
- i. LPR 5000.2, Procurement Initiator's Guide
- j. LPR 5300.1, Product Assurance Plan
- k. LPR 7120.5, Space Flight Project Practices Handbook
- l. LPR 7130, Project and Task Review Procedural Requirements
- m. LPR 7120.4, LaRC Technical Authority Implementation Plan
- n. LPR 7120.7, Space Flight Independent Life Cycle Review Procedural Requirements
- o. LMS-CP-1725, Export Control
- p. LMS-CP-2310, Electronic Storage and Archival System (Document and Data Management)
- q. LMS-CP-4756, Handling, Preservation, Storage, and Shipping of Flight Hardware and Ground Support Equipment
- r. LMS-CP-5526, Product Requirements Development and Management Procedure
- s. LMS-CP-8041, Flight Projects Directorate Master Configuration and Data Management Plan

P.5 MEASUREMENT/VERIFICATION

Verification will be accomplished by inspection as part of the LaRC Internal Audit process.

P.6 CANCELLATION

LPR 7123.1, dated July 20, 2010

Original signed on file
Acting Associate Director

Approved for public release via the Langley Management System. Distribution is unlimited.

1. RESPONSIBILITIES

- 1.1 The LaRC Center Director, or designee, is responsible for the implementation of the SE policies, processes, and procedures at LaRC.
- 1.2 The Chair of the LaRC Center Management Council (CMC), or designee, serves as the LaRC Designated Governing Authority (DGA) to approve systems engineering implementation for LaRC Type A-D and Type E with LCC > \$25M, Programs/Projects. For more information on LaRC Project types, refer to Appendix D.
- 1.3 The LaRC Chief Engineer, or designee:
 - 1.3.1 Serves as the LaRC DGA to approve systems engineering implementation of LaRC Type E with LCC < \$25M and Type F with \$25M < LCC < \$10M Programs/Projects;
 - 1.3.2 Reviews Type A-D and Type E with LCC > \$25M Programs/Projects systems engineering implementation prior to DGA review/approval; and
 - 1.3.3 Ensures all directorates involved in the engineering work review the Systems Engineering Management Plan (SEMP) (for a Type A-D or Type E with LCC > \$25M Program/Project) or other appropriate documentation of systems engineering implementation plans (for a Type E with LCC < \$25M Program/Project).
- 1.4 The Director of the responsible engineering directorate (Engineering Directorates at Langley are specified in LPR 7120.4) providing the Program/Project, Chief Engineer (or Lead Systems Engineer if no Chief Engineer), or designee:
 - 1.4.1 Ensures the Chief Engineer (or Lead Systems Engineer or other appropriate person) for the Program/Project prepares the SEMP (for a Type A-D or Type E with LCC > \$25M Program/Project) or other appropriate documentation (for a Type E or Type F with LCC < \$25M Program/Project) in accordance with this LPR.
 - 1.4.2 Ensures all directorates involved in the engineering work of the Program/Project concur on the SEMP or other appropriate documentation.
 - 1.4.3 Ensures compliance with the approved SEMP or other appropriate documentation.
 - 1.4.4 Serves as the LaRC DGA to approve systems engineering implementation for Type F and LCC < \$10M Programs/Projects.
- 1.5 The Program/Project Manager (PM), or designee:

- 1.5.1 Ensures a SEMP (for a Type A-D or Type E with LCC >\$25M Program/Project) or other appropriate documentation (for a Type E with LCC<\$25M or Type F Program/Project) is written to define Program/Project implementation of SE requirements and processes;
- 1.5.2 Ensures review and approval of the SEMP or other appropriate documentation by the appropriate SE DGA;
- 1.5.3 Controls the SEMP or other appropriate documentation under Program/Project control processes;
- 1.5.4 Provides the design team with statutory, regulatory, and Agency mandatory requirements, relevant information from previous similar designs, and any other requirements for product design and development.
- 1.5.5 Ensures that software developed within NASA or acquired complies with NPR 7150.2, for systems that contain software (see NPR 7123.1, Section 2.1.5.3).
- 1.6 The Program/Project Systems Engineering Team (SET):
 - 1.6.1 Prepares the SEMP or other appropriate documentation as required by the DGA.
 - 1.6.2 Executes or oversees the execution of the Program/Project systems engineering processes.
- 1.7 For Programs/Projects involving more than one Center, the lead organization develops documentation to describe the hierarchy and reconciliation of plans for implementing system engineering processes and requirements that are applicable to all Centers involved. However, the LaRC Center Director, Engineering Director and Chief Engineer are responsible to ensure all LaRC work in support of these efforts is in compliance with this LPR and NPR 7123.1.
- 1.8 Responsibilities for various activities associated with the SEMP or other appropriate documentation of the systems engineering implementation are summarized in Table 1-1. In each case the DGA has final approval authority.

LaRC Project Type¹ and Life-Cycle Cost	A-E >\$25M	E, F \$10-\$25M	F <\$10M
CMC Chair	DGA		
LaRC Chief Engineer	Reviews	DGA	
Responsible Engineering Director²	Reviews	Reviews	DGA
Program/Project Manager	Concurs	Concurs	Concurs
Systems Engineering Team (SET)	Prepares	Prepares	Prepares
Notes: 1) LaRC Project Type defined in LaRC 7120.5 Tailoring Tool. Project Type should be documented and approved in the Project Formulation Agreement. If project type is not specified, the DGA as determined by project LCC should resolve any ambiguity about type classification. 2) Engineering Directorates at Langley are specified in LPR 7120.4.			

Table 1-1 Responsibilities for the SEMP or alternative documentation of systems engineering implementation

2. PROCEDURE

2.1 Program/Project Systems Engineering

2.1.1 The Program/Project Systems Engineering Life Cycle is defined as a set of activities, processes and reviews that enables the smooth, incremental development of products essential to successfully achieving the Program/Project goals.

2.2 The Systems Engineering Management Plan (SEMP)

2.2.1 The purpose of a SEMP is to provide a single, integrated technical planning document which addresses the systems engineering management and implementation for systems and subsystems for in-house and contracted Programs/Projects.

Req. 001: Each Type A-D and Type E with LCC>\$25M Program/Project (refer to Appendix D) SET shall provide to the DGA a SEMP as described in Appendix D.4 “SEMP Annotated Outline” of NPR 7123.1, NASA Systems Engineering Processes and Requirements.”

Rationale: [The SEMP is required by NPR 7123.1. The SEMP provides the specifics of the technical effort and describes what technical processes will be used, how the processes will be applied, how the project will be organized to accomplish its activities, and the cost and schedule associated with accomplishing the activities. At LaRC, a stand-alone SEMP is required for any Type A-D and Type E with LCC>\$25M Program/Project because of their size and/or visibility.]

Trace: [NPR 7123.1B Sections, 6.2.1, 6.2.2, 6.2.3]

Allocation: [LPR 7120.5, LPR 7120.7]

Verification Method: [Inspection]

Req. 002: Each Type E with LCC<\$25M and Type F Program/Project SET shall provide to the DGA the documentation of the material typically found in a SEMP (see Appendix D.4 “SEMP Annotated Outline” of NPR 7123.1) in the manner and form agreed to with the DGA.

Rationale: [Smaller projects do not have the resources to develop a full SEMP, so the DGA decides what needs to be documented and the form that documentation will take. For example, the material may be documented in the project plan, as an appendix to the project plan, or in some other appropriate form as determined by the DGA.]

Trace: [NPR 7123.1B Sections 6.2.1, 6.2.2, 6.2.3]

Allocation: [LPR 7120.5, LPR 7120.7]

Verification Method: [Inspection]

- 2.2.2 The SEMP and the project plan are coordinated to ensure compatibility with the allocated resources/enabling products (cost, schedule, personnel, and facilities), milestones and deliverables. The SEMP is used to identify and evaluate the required technical teams' performances. The SEMP is also used in the technical risk assessment and deriving the progress measurement criteria.
- 2.2.3 For projects with significant portions of the engineering work contracted out, the LaRC SEMP scopes and plans the NASA portion of the project implementation of the systems engineering common technical processes before, during, and at the completion of the contracted effort. This includes planning the technical team's involvement in the Request for Proposal (RFP) preparation, in source selection activities, acceptance of deliverables, and storage and disposal of residual hardware.
- 2.2.3.1 Depending upon the scope and content of the contracted effort, a contractor may be required to develop and maintain a SEMP or other appropriate documentation for their contracted effort.

2.2.4 SEMP Maintenance

Req. 003: Each Program/Project SET shall update the SEMP or alternate documentation as changes to the system engineering plan evolve throughout the project (e.g., at major life cycle reviews).

Rationale: [The SEMP (or alternate documentation) is not as useful if it is outdated. As changes to the SEMP occur they are typically updated and approved as part of the project review processes.]

Trace: [NPR 7123.1 section 6.2.2]

Allocation: []

Verification Method: [Inspection]

Req. 004: The DGA shall review and approve or disapprove the SEMP alternate documentation when updated as part of the project review processes.

Rationale: [The SEMP (or alternate documentation) is not as useful if it is outdated. Approval at this frequency is required by NPR 7123.1.]

Trace: [NPR 7123.1 section 6.2.5]

Allocation: []

Verification Method: [Inspection]

2.3 Systems Engineering Common Technical Processes

- 2.3.1 It is the responsibility of the Center Director to ensure the 17 common technical processes are implemented in Center Policies/Procedures. It should be emphasized that the Practices for Common Technical Processes do not represent additional requirements that must be implemented by the technical team. LaRC compliance of the 17 common technical processes as detailed in NPR 7123.1B Appendix H Table H.1 Compliance Matrix is documented in Appendix E of this LPR.

The implementation of the 17 Common Technical Processes are described in the SEMP (or alternate documentation) as discussed in NPR 7123.1, Appendix D.4.7.

Trace: [NPR 7123.1B Sections 6.2.3, 3.2.2.1, 3.2.3.1, 3.2.4.1, 3.2.5.1, 3.2.6.1, 3.2.7.1, 3.2.8.1, 3.2.9.1, 3.2.10.1, 3.2.11.1, 3.2.12.1, 3.2.13.1, 3.2.14.1, 3.2.15.1, 3.2.16.1, 3.2.17.1, 3.2.18.1]

Allocation: [LPR 7120.5, CP-5526, LPR 5000.2, LPR 5300.1, CP-4756, LPR 1440.7, LPR 8040.1, CP-1725, CP-2310, LPR 7120.7, LPR 7130, LAPD 7000.2, CP-5621]

Verification Method: [Inspection]

2.4 Programs and Projects Systems Engineering Requirements

- 2.4.1 Systems engineering requirements compliance for programs and projects is documented by appending a tailored Compliance Matrix NPR 7123.1B (see Appendix H.2) to the Systems Engineering Management Plan (SEMP). LaRC Program/Projects should use the LaRC Tailoring Tool (Sheet "NPR7123.1B Appendix H.2") to tailor and complete the compliance matrix. The tailoring tool can be found at: <https://nx.larc.nasa.gov/dsweb/View/Collection-31948>.

Req. 005: Each Type A-D and Type E with LCC>\$25M Program/Project shall complete the NPR Compliance Matrix (NPR 7123.1B Appendix H.2). It is recommended to use the LaRC Tailoring Tool.

Rationale: [The individuality of each Program/Project is appreciated and some practices that work for some Programs/Projects do not work well for others, hence the intent of this requirement to give the Program/Project sufficient flexibility. For instance, the SET may conclude that the overhead associated with

particular practices, or perhaps even entire processes exceed the benefit derived from particular practices, or they may conclude that alternative practices are better suited to the Program/Project.]

Trace: [NPR 7123.1 Section 2.1.5.2.]

Allocation: [LPR 7120.5, CP-5526, LPR 5000.2, LPR 5300.1, CP-4756, LPR 1440.7, LPR 8040.1, CP-1725, CP-2310, LPR 7120.7, LPR 7130, LAPD 7000.2, CP-5621]

Verification Method: [Inspection]

2.4.2 Because Type E with LCC<\$25M and Type F Programs/Projects are typically more resource-constrained than Type A-D Programs/Projects their SETs are not required to document reasons for departing from the practices.

2.4.3 Approval of the SEMP or equivalent documentation as appropriate by the DGA constitutes approval of the systems engineering requirements tailoring.

3. RECORDS

The following records are required by this LPR:

Record	Custodian
Approved SEMP or other equivalent documentation	PM or designee

Additional records may be required, depending upon the detailed contents of the SEMP (or equivalent documentation).

4. TAILORING AND WAIVERS

4.1 Waivers to requirements specific to this LPR can be granted by the LaRC Center Director or his/her designee.

Req. 006: The PM of the Program/Project shall provide any waiver requests to the LaRC Center Director (or designee) in writing, signed by the PM, and accompanied by evidence of concurrence by the relevant Project Chief Engineer or the Project Lead Systems Engineer and the Program/Project sponsor (the Principal Investigator or other appropriate person).

Rationale: [The request is in writing to ensure a document trail. The signature of the PM ensures his/her awareness and support of the waiver request. The concurrence of the Project Chief Engineer or the Project Lead Systems Engineer ensures that the engineering aspects have been reviewed. The concurrence of the sponsor ensures that the sponsor is aware of the request – i.e., there is an informed customer.]

Trace: []

Allocation: []

Verification Method: [Inspection]

- 4.2 In cases where the identity of the Project Chief Engineer or Project Lead Systems Engineer and/or the Project sponsor are unclear, the LaRC Chief Engineer or his/her designee may assign individuals to act in those roles or may waive the requirement for concurrence.

Req. 007: The PM of the Program/Project shall maintain all waiver documentation.

Rationale: [The Program/Project is the responsible party for maintaining project documentation.]

Trace: []

Allocation: []

Verification Method: [Inspection]

- 4.3 Any tailoring or waivers to requirements of this LPR involving other LMS documents will be approved in accordance with the tailoring or waiver processes applicable to those LMS documents.

APPENDIX A. DEFINITIONS

A.1 Customer – The organization or individual that has requested a product and will receive the product to be delivered. The customer may be an end user of the product, the acquiring agent for the end user, or the requestor of the work products from a technical effort. Each product within the system hierarchy has a customer.

A.2 Designated Governing Authority – The management entity above the program or project with technical oversight responsibility.

A.3 Systems Engineering Team (SET) – The SET is comprised of the individuals that prepare the systems engineering implementation plan and execute the approved plan throughout the project's life cycle. For small projects with highly tailored systems engineering requirements, the SET may be a SE cognizant engineer or researcher with SE responsibilities as well as other project responsibilities.

A.4 Stakeholder – A group or individual who is affected by or in some way accountable for the outcome of an undertaking. Stakeholders include all who are involved in the Program/Project – end-users, designers, manufacturing, test, and quality personnel, including those who may not be directly involved with doing the processing work.

A.5 Technical Requirements – Statements defining necessary performance characteristics of a product. Technical requirements are stated in a verifiable manner such that pass/fail or quantitative assessment criteria are specified.

A.6 Validation – Testing, possibly under simulated conditions, to ensure that a finished product works as required.

A.7 Validation (of a product) – Proof that the product accomplishes the intended purpose. Validation may be determined by a combination of test, analysis, and demonstration.

A.8 Verification – The process of proving or demonstrating that a finished product meets design specifications and requirements.

A.9 Verification (of a product) – Proof of compliance with specifications. Verification may be determined by test, analysis, demonstration, and inspection.

APPENDIX B. ACRONYMS

CMC	Center Management Council
CP	Center Procedure
DGA	Designated Governing Authority
LAPD	Langley Policy Directive
LaRC	Langley Research Center
LCC	Life-Cycle Cost
LMS	Langley Management System
LPR	Langley Procedural Requirements
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirements
PM	Program, Project
SE	Systems Engineering
SEMP	Systems Engineering Management Plan
SET	Systems Engineering Team

APPENDIX C. REQUIREMENTS LIST FOR THIS LPR

Requirement Number	Prior Paragraph Number	Description (these are abbreviated; the full text of the LPR paragraph applies)
001	2.2.1	Each Type A-D and Type E with LCC>\$25M Program/Project (refer to Appendix D) SET shall provide to the DGA a SEMP as described in Appendix D.4 "SEMP Annotated Outline" of NPR 7123.1, "NASA Systems Engineering Processes and Requirements."
002	2.2.1	Each Type E with LCC<\$25M and Type F Program/Project SET shall provide to the DGA the documentation of the material typically found in a SEMP (see Appendix D.4 "SEMP Annotated Outline" of NPR 7123.1) in the manner and form agreed to with the DGA.
003	2.2.4	Each Program/Project SET shall update the SEMP or alternate documentation as changes to the system engineering plan evolve throughout the project (e.g., at major life cycle reviews).
004	2.2.4	The DGA shall review and approve or disapprove the SEMP alternate documentation when updated as part of the project review processes.
005	2.3.1	Each Type A-D and Type E with LCC>\$25M Program/Project shall complete the NPR Compliance Matrix (NPR 7123.1B Appendix H.2). It is recommended to use the LaRC Tailoring Tool.
006	4.1	The PM of the Program/Project shall provide any waiver requests to the LaRC Center Director (or designee) in writing, signed by the PM, and accompanied by evidence of concurrence by the relevant Project Chief Engineer or the Project Lead Systems Engineer and the Program/Project sponsor (the Principal Investigator or other appropriate person).
007	4.2	The PM of the Program/Project shall maintain all waiver documentation.

APPENDIX D. TYPE OF PROGRAM/PROJECT

D.1 LaRC has extended NPR 8705.4 risk classification for payloads to established six types of programs and projects, where Type A requires the most rigorous processes (e.g., human spaceflight) through Type F, which allows for more relaxed rigor (e.g., small technology demonstration). The classification is done at program/project initiation and documented in the program/project Formulation Agreement. Further information on project types can be found in the Langley Tailoring Tool:
<https://nx.larc.nasa.gov/dsweb/Services/Document-314296>

D.2 Several factors are considered when determining and documenting the project type. Life Cycle Cost (LCC) is a key factor and initially used to classify project type, but other factors considered are: Priority (Criticality to Agency Strategic Plan) and Acceptable Risk Level, National Significance, Complexity, Mission Lifetime (Primary Baseline Mission), Launch Constraints, and Alternative Research Opportunities or Re-flight Opportunities. Agency-level Programs and Projects (those identified in the NASA Meta Data Manager database) are classified as Type A-D as agreed to by the MDAA and Center Director. For Type E-F projects, if the Type has not been explicitly determined, the PM should work with the DGA (as specified by LCC) to establish the appropriate level of project review and concurrence of systems engineering practices for the program/project. Typically Programs/Projects are initially classified at the highest level corresponding to planned life-cycle costs (LCC) as indicated in Table 1-1. For instance, a Program/Project expected to have an LCC of \$20M would be considered as Type E. Similarly, a Program/Project with an expected annual cost of \$3M per year for each of 5 years (LCC=\$15M) would also be considered as Type E. For each program/project, the DGA according to the initial classification communicates the initial classification to the DGA of the next higher level of classification.

APPENDIX E. NPR 7123.1B TABLE H.1 COMPLIANCE MATRIX FOR LARC

The following matrix shows Langley's compliance with the Center Director requirements from NPR 7123.1 that are owned by OCE. The compliance rationale is given for each requirement, and the Center's approach to meeting requirements through Center and Agency processes, procedures, and requirements is described. Project-specific Systems Engineering requirements are addressed and tailored when appropriate by project teams and approved through the designated authority as described in this LPR.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-01	2.1.4.3.a	Center Directors shall perform the following activities: establish policies, procedures, and processes to execute the requirements of this SE NPR.	The requirements of this NPR are to be flowed into Center-level command media for execution. This may require not only Center-level requirements, but also policy statements, work instructions, or other supporting or enabling processes. It is the responsibility of the Center Directors or designees to ensure that this occurs.	OCE	FC	This document, LPR 7123.1, has been established for the specific purpose of establishing Center systems engineering processes and guidance.
SE-02	2.1.4.3.b	Center Directors shall perform the following activities: assess and take corrective actions to improve the execution of the requirements of this SE NPR.	Continual improvement of Agency and Center processes is necessary to ensure they are efficient and effective. It is the responsibility of the Centers to bring forward any recommendations for improvement of this NPR.	OCE	FC	This LPR is periodically reviewed and revised. LMS-CP-1410.2 specifies the Langley Management System process for updates and review.
SE-03	2.1.4.3.c	Center Directors shall perform the following activities: select appropriate standards applicable to projects under their control.	It is the responsibility of the Center organizations to identify which Agency and/or Center technical standards should be applied to the programs and projects within their purview. These will be recommended to the programs/projects through the technical authority lines.	OCE	FC	Projects are designated as 7120.8, Research and Technology, or 7120.5, Spaceflight. The Technical Standards process flows from NPR 7120.10.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-04	2.1.4.3.d	Center Directors shall perform the following activities: Complete the compliance matrix, as tailored, in Appendix H.1 for those requirements owned by the Office of Chief Engineer, and provide to the OCE upon request.	The Centers are to fill out the compliance matrix in Appendix H.1 to indicate how the OCE-owned requirements of this NPR have been flowed into Center-level processes. This ensures that the OCE requirements of the Agency are flowed into the Centers and that any waiver/deviation from the Agency requirements has been identified and approved by the OCE.	OCE	FC	This table shows compliance with this requirement.
SE-07	3.2.2.1	Center Directors or designees shall establish and maintain a Stakeholder Expectations Definition process to include activities, requirements, guidelines, and documentation for the definition of stakeholder expectations for the applicable product layer.	This requirement ensures that the Centers identify how they will gather and address stakeholder expectations. This ensures that the project will gain a thorough understanding of what the customer and other stakeholders expect out of the programs/projects.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5 and LPR 7510.1.
SE-08	3.2.3.1	Center Directors or designees shall establish and maintain a Technical Requirements Definition process to include activities, requirements, guidelines, and documentation for the definition of technical requirements from the set of agreed upon stakeholder expectations for the applicable product layer.	This requirement ensures that the Centers identify how they will select and gain agreement on the technical requirements for the program/project.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
						Center processes supporting this requirement include LPR 7120.5 and LPR 7150.2.
SE-09	3.2.4.1	Center Directors or designees shall establish and maintain a Logical Decomposition process to include activities, requirements, guidelines, and documentation for logical decomposition of the validated technical requirements of the applicable product layer.	This requirement ensures that the Centers identify how they will take the technical requirements for the program/project and glean from them what is needed to accomplish them (functional block diagrams, timing, architectures, etc.). This places the requirements into context and ensures they are understood well enough to begin the design process.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.
SE-10	3.2.5.1	Center Directors or designees shall establish and maintain a Design Solution Definition process to include activities, requirements, guidelines, and documentation for designing product solution definitions within the applicable product layer that satisfy the derived technical requirements.	This requirement ensures that the Centers identify how they will take the information from the stakeholder expectations, requirements, and logical decomposition and perform the design function. Since all designs are unique, this will describe the general steps that are taken. The specifics for each of the program/projects will be documented in the SEMP.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
						this requirement include LPR 7120.5.
SE-11	3.2.6.1	Center Directors or designees shall establish and maintain a Product Implementation process to include activities, requirements, guidelines, and documentation for implementation of a design solution definition by making, buying, or reusing an end product of the applicable product layer.	This requirement ensures that the Centers identify how they will execute the designs, whether through buying items off the shelf or contracting to have them built, building/coding them within the Center, or reusing products already developed by another program/project. The specifics for how each program/project will make this determination for the various components/assemblies within the product hierarchy are documented in the SEMP.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.
SE-12	3.2.7.1	Center Directors or designees shall establish and maintain a Product Integration process to include activities, requirements, guidelines, and documentation for the integration of lower level products into an end product of the applicable product layer in accordance with its design solution definition.	This requirement ensures that the Centers identify how they will approach the integration of products within successive levels of the product hierarchy. This ensures that planning is performed that will enable a smooth integration of products into higher level assemblies.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
						Center processes supporting this requirement include LPR 7120.5
SE-13	3.2.8.1	Center Directors or designees shall establish and maintain a Product Verification process to include activities, requirements/specifications, guidelines, and documentation for verification of end products generated by the product implementation process or product integration process against their design solution definitions.	This requirement ensures that the Centers identify how they will verify that the end products will comply with the technical requirements.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.
SE-14	3.2.9.1	Center Directors or designees shall establish and maintain a Product Validation process to include activities, requirements, guidelines, and documentation for validation of end products generated by the product implementation process or product integration process against their stakeholder expectations.	This requirement ensures that the Centers identify how they will show that the end products will meet the stakeholder expectations in the intended environment. This is in addition to verifying that they meet the stated requirements and ensures the stakeholder is getting what was expected.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
						this requirement include LPR 7120.5.
SE-15	3.2.10.1	Center Directors or designees shall establish and maintain a Product Transition process to include activities, requirements, guidelines, and documentation for transitioning end products to the next higher level product layer customer or user.	This requirement ensures that the Centers identify how they will handle the end products as they move from one location to another. This includes shipping, handling, transportation criteria, security needs, and receiving facility storage needs. It ensures that receiving facilities are ready to accept the product and that no damage occurs to the product during handling and transportation.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-16	3.2.11.1	Center Directors or designees shall establish and maintain a Technical Planning process to include activities, requirements, guidelines, and documentation for planning the technical effort.	This requirement ensures that the Centers identify how they will perform and document all the technical planning for the program/project. This includes all plans developed for the technical effort —Systems Engineering Management Plans, risk plans, integration plans, and V&V plans. This ensures that the program/project teams are thinking ahead for the work to be performed and capturing that information so it can be communicated to the rest of the team, customers, and other stakeholders.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.
SE-17	3.2.12.1	Center Directors or designees shall establish and maintain a Requirements Management process to include activities, requirements, guidelines, and documentation for management of requirements throughout the system life cycle.	This requirement ensures that the Centers identify how they will handle tracking and changes to the baselined set of requirements. It defines who has authority to submit and approve changes and how requirements are tracked as they flow down to other elements in the product breakdown structure. This ensures that changes to requirements are evaluated and that their impacts are understood and communicated to the rest of the team.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-18	3.2.13.1	Center Directors or designees shall establish and maintain an Interface Management process to include activities, requirements, guidelines, and documentation for management of the interfaces defined and generated during the application of the system design processes.	This requirement ensures that the Centers identify how they will manage the internal and external interfaces of their end product. This will ensure compatibility when the various parts of the system are brought together for assembly/integration.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.
SE-19	3.2.14.1	Center Directors or designees shall establish and maintain a Technical Risk Management process to include activities, requirements, guidelines, and documentation for management of the risk identified during the technical effort.	This requirement ensures that the Centers identify how they will handle the technical portions of the program/project risks and report them for inclusion with the programmatic risk portions. It ensures that the technical aspects of risks to the program/project's successful execution are captured and reported to program/project management who will be developing the overall risk posture.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-20	3.2.15.1	Center Directors or designees shall establish and maintain a Configuration Management process to include activities, requirements, guidelines, and documentation for configuration management.	This requirement ensures that the Centers identify how they will perform configuration management of the end products, enabling products and other work products key to the program/project. The technical products to be controlled are identified and tracked to ensure that the team knows what the configuration of their system is at all phases of the life cycle.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5 and LPR 1740.4.
SE-21	3.2.16.1	Center Directors or designees shall establish and maintain a Technical Data Management process to include activities, requirements, guidelines, and documentation for management of the technical data generated and used in the technical effort.	This requirement ensures that the Centers identify how they will handle all the technical data that is generated by the program/project. This will include all data needed to manage, operate, and support the system products over the life cycle. It ensures that the data is available and secure when needed.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5.

Req ID	SE NPR Paragraph	Requirement Statement	Rationale	Req Owner	Comply?	Justification Compliance Rationale
SE-22	3.2.17.1	Center Directors or designees shall establish and maintain a Technical Assessment process to include activities, requirements, guidelines, and documentation for making assessments of the progress of planned technical effort and progress toward requirements satisfaction.	This requirement ensures that the Centers identify how they will assess the progress of the program/project's technical efforts, including life-cycle reviews. It ensures that the program/project team, customers, and other key stakeholders know how the effort is progressing and if additional actions are needed to resolve issues prior to becoming too costly.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5, LPR 7120.7, and LPR 7130.
SE-23	3.2.18.1	Center Directors or designees shall establish and maintain a Decision Analysis process to include activities, requirements, guidelines, and documentation for making technical decisions.	This requirement ensures that the Centers identify how they will make and document key technical decisions. It helps to ensure that all team members know who can make decisions, what their authority levels are, and where to go to gain an understanding of what key decisions have been made.	OCE	FC	Designated Authority delegation for SE requirements is specified in this LPR. Projects document SE plans in the SEMP or comparable documentation. Oversight is through pre-CMCs and EPTR as defined in LPR 7130, Engineering Project and Task Review Procedural Requirements. Additional Center processes supporting this requirement include LPR 7120.5, LPR 7123, and LPR 7120.4.

APPENDIX F. REFERENCES

The following documents may be useful to individuals in addressing the requirements of this LPR.

- a. NRRS 1441.1, NASA Record Retention Schedules
- b. NASA/SP-2007-6105, NASA Systems Engineering Handbook
- c. NPR 8000.4A, Agency Risk Management Procedural Requirements
- d. CMMI® Guidelines for Process Integration and Product Improvement – Addison-Wesley

APPENDIX G. LARC-SPECIFIC ENGINEERING BEST PRACTICES

LaRC Chief Engineer Board approved 9-12-2013

Preface to Appendix G

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G.1. Introduction

The LaRC-Specific Engineering Best Practices contained in this appendix are those considered by the LaRC Chief Engineer and the members of the Chief Engineer's Board to be most appropriate and useful to the development of space and ground support systems. However, these Best Practices should also be considered, where applicable, for aircraft-borne systems and their associated ground support systems.

G.2. Applicability

Although these Engineering Best Practices are not requirements, they are to be considered in the development of space systems, including instruments, research instrumentation flown on aircraft and balloons, and the associated ground support equipment, inasmuch as the individual practices are applicable to the situation at hand. Further, it is the intent that these practices become engrained in the practitioners such that they will automatically refer to and use them, and also in the reviewers such that they will ask questions about them at life-cycle reviews.

It is also noted that in case of a disagreement between any of the best practices shown in this appendix and any NPR or LPR, the NPR or LPR governs.

G.3. Authority and Maintenance

The LaRC Chief Engineer (LaRC CE) has the responsibility and authority for developing and maintaining this Appendix (G) containing LaRC-Specific Engineering Best Practices. This responsibility and authority is carried out with the advice of the LaRC Chief Engineer's Board (CEB) and with the support of the LaRC Appendix G Section Owners in the following manner:

The basic tenets of maintaining the LaRC-Specific Engineering Best Practices Appendix are shown below.

- Owners are responsible for their section of the Best Practices Appendix. The ownership of each section is assigned to an entity within LaRC. The organizational ownership of each section is shown in Table G1.
- Owners are ultimately responsible for proposing any changes to their section of the Appendix in the form of change requests.
- Recommendations for changes to Best Practices can come from different sources:
 - Individuals.
 - NASA-Wide Lessons Learned.
 - LaRC Lessons Learned Committee – When the committee deems a lesson is appropriate for inclusion in the LaRC Lessons Learned Repository.
- All recommendations for changes are routed through the LaRC Chief Engineer.
- The Chief Engineer, with input from Chief Engineer's Board, is responsible for governing the change request process and for ultimately dispensing with the change requests.

The process for maintaining the Appendix and the associated practices is shown in Figure G-1. Discussion of the process follows:

- Recommendations for a best practice can come from different sources. These include individuals, NASA-wide Lessons Learned that are transmitted to the LaRC CE, or LaRC Lessons Learned that are judged by the LaRC Lessons

Learned Committee to be appropriate for consideration in the LaRC Best Practices.

- The LaRC CE will distribute any of these recommendations considered appropriate to the CEB for review.
- The board will consider the recommendations and the CE will decide, with CEB input, if LaRC should develop a new practice, modify or delete an existing practice, or do nothing.
- Assuming that a change is required, the CE will assign the appropriate section owner the task of developing the change request to include the new or modified practice.
- The section owner will develop the change request for the new or modified practice and present it to the board for approval. This change request will provide a practice with the standard information of Practice, Rationale, and Implementation and a proposed paragraph number indicating the location of the proposed practice in the Appendix.
- The board will review the change request and the CE will decide if the request is ready for inclusion in the Appendix, if it needs more work by the section owner, or if it should be deleted. If the change goes into the Appendix, the Appendix manager will be notified to implement the change and inform the LaRC Lessons Learned Committee.

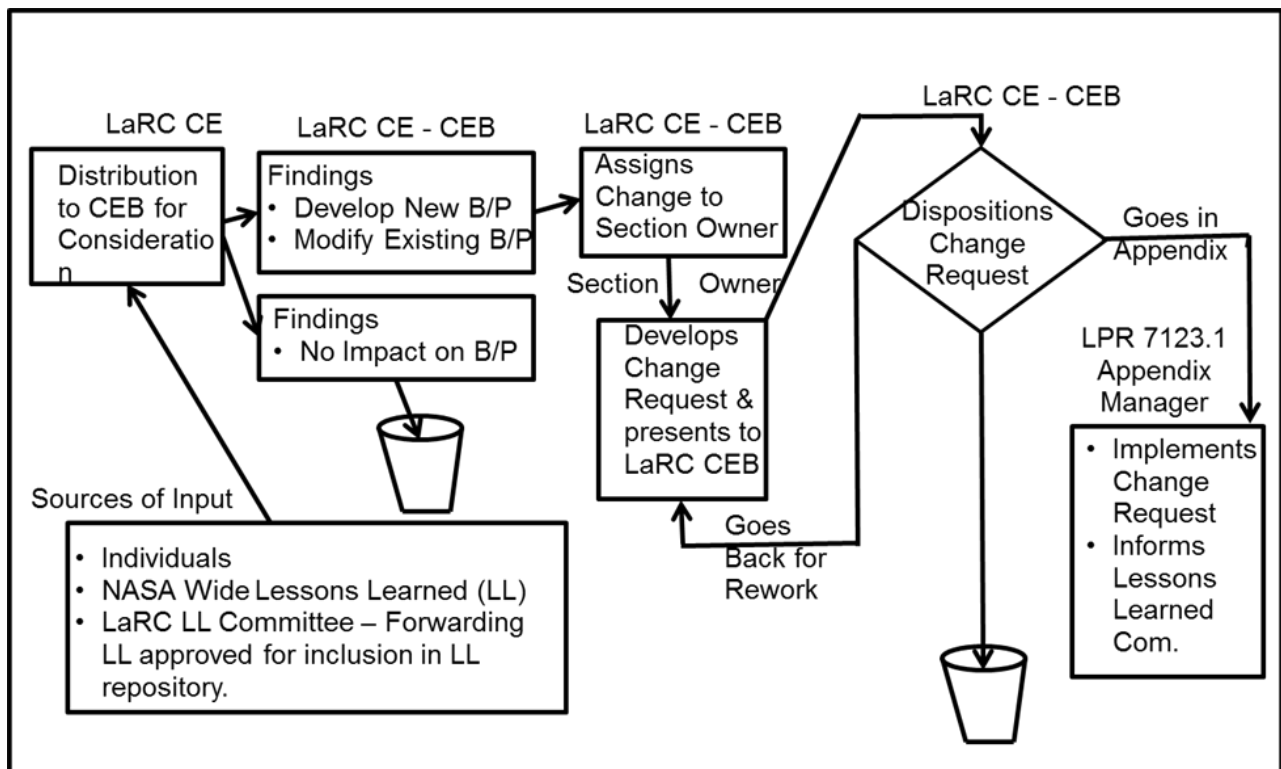


Figure G-1 - Best Practice Change Request Process

Sections	Responsible Organizational Owner
1.0 – Assembly Integration and Test	D210 Systems Integration and Test Branch Branch Head
2.0 – Command and data Handling	D203 Electronic Systems Branch Branch Head
3.0 – Contamination Control	D210 Systems Integration and Test Branch Branch Head
4.0 – Electronic Systems	D203 Electronic Systems Branch Branch Head
5.0 – Fluids	Standard Practice Engineer for Flight Systems - Pressure Systems Committee (Established by LaPD 1150.2)
6.0 – Guidance navigation and Control	D316 Dynamic Systems and Control Branch Branch Head
7.0 – Mechanical Systems	D202 Mechanical Systems Branch Branch Head
8.0 – Operations and Ground Systems	E605 Management Systems Office
9.0 – Reliability	C202 Mission Assurance Branch Branch Head
10.0 – Software	D207 Flight Software Systems Branch Branch Head
11.0 – Systems	D209 - Systems Engineering and Engineering Methods Branch (SEEMB) Branch Head

Table G-1 - Appendix G Section Owners

G.4. Change Management for Best Practices

The following change management process will be used to maintain currency in the Best Practices and also maintain traceability from the previous baselines to the present baseline.

- Baselines will be dated and maintained. Previous baselines will be archived.
- Best Practices will be periodically updated. When this occurs, a redline version of the Best Practices will be generated showing the from-to and the reason for the change.
- Upon approval by the LaRC CE of the redline version of the Best Practices, a new, dated, baseline will be generated showing the current Best Practices.
- The resulting detailed Best Practices will be maintained in the searchable data base ([Langley Form 209](#)) and are included only in summarized titles in this appendix (See section 0). The red-lined version of the Best Practices will be archived in order to maintain a traceable path to the previous baseline.

G.5. Change Management Rules Regarding the Best Practices Database

- A change column will be maintained in the searchable data base showing the date of the change and describing the nature of the change.
- If a practice is deleted, the title of the practice and the practice number will remain to maintain the proper cross-references from previous baselines and within the current practices themselves.
- Once a practice is in the document it will remain in place for the above reasons.
- New practices will be added at the end of the proper section.

G.6. Best Practice Structure

The Best Practices as shown in this appendix are grouped in different technical areas to assist the user in quickly finding those practices of greatest interest. Each practice contains a *Title* and three pieces of additional information. The three pieces of information are the *Best Practice* itself, the *Rationale* or the reason for that practice to exist, and the *Implementation* that describes how the practice can be carried out and what product or action should be completed by the reviews in the project life cycle.

The implementation sections of the Best Practices state that certain products should be available by various reviews, such as PDR or CDR. It is intended that these reviews refer to the subsystem PDR or CDR, or the system level reviews if the subsystem level reviews are not held.

Section 0 contains an abbreviated listing of the Best Practices (Headings and Titles) for quick reference and location. To obtain the full context of the Best Practices and related additional information, see [LF 209](#) per Section 0.

G.7. Use of Acronyms and the Project Life Cycle

In many cases acronyms have been used in the discussion of individual best practices. In those cases, an attempt has been made to define the acronyms within the individual best practice discussion. However, the acronyms for the standard project reviews used in NPR 7120.5 are not defined in the individual best practices discussions, as they are used multiple times. The acronyms for those reviews that have been cited in this Appendix are defined below.

MCR Mission Concept Review
 SRR System Requirements Review
 MDR Mission Definition Review
 PDR Preliminary Design Review
 CDR Critical Design Review
 IRR Integration Readiness Review
 SIR System Integration Review
 ORR Operational Readiness Review
 FRR Flight Readiness Review

G.8. LaRC-Specific Engineering Best Practices (Abbreviated)

(Headings and Titles Only)

Item Number	LaRC-Specific Engineering Best Practices
1.00	Assembly Integration and Test (AIT)
1.01	AIT - General
1.01.01	Verification Methods Hierarchy
1.01.02	Test As You Fly
1.01.03	Qual Testing Expectations
1.01.04	Ground Support Equipment (GSE) Usage
1.01.05	Final Mechanical Walkthrough

Item Number	LaRC-Specific Engineering Best Practices
1.02	AIT - System Level Testing
1.02.01	System Alignment Verifications
1.02.02	Functional Performance Verification
1.02.03	Inter-system Mechanical Fit Check
1.02.05	Mechanical Environmental Testing
1.02.06	Unique Launch Site Operations
1.02.07	Launch Site Testing of Flight System
1.02.08	Safety Precautions - Test and Operating Procedures
1.02.09	Re-verification
1.03	AIT - Models and Test Beds
1.03.01	Early Identification of Test Beds
1.03.02	Test Bed Supporting Orbital Operations
2.00	Command & Data Handling (C&DH) (Also see section 4.07 - Electronic Systems - Telemetry)
2.01	C&DH – General
2.01.01	Use of Data Editing, Data Compression
2.01.02	Minimum Number of Operational Data Transfer Modes
2.01.03	Hierarchical Emergency Data Modes
2.01.04	Assessing Health Status
2.01.05	Data for Anomaly Determination

Item Number	LaRC-Specific Engineering Best Practices
2.01.06	Automated Transfer of Data
2.01.07	Override Requirement Assessment
2.01.08	Self Check/Diagnostic Capability
2.01.10	Automated Fault Detection
2.01.11	Safe Mode Identification
2.01.12	Bulk Data Storage
2.01.13	Sensor Reliability for Autonomous Control
2.01.14	Avoidance of Inadvertent S/C Off Commands
2.01.15	Avoidance of Inadvertent Transceiver Off Commands
2.01.16	Configuration Control of Command Procedures and Databases
2.01.18	Inter-system Electrical Interface Verification
2.01.19	Command Systems Checks
2.01.20	Command Confirmation
2.01.21	S/C Autonomy for Time-Critical Operations
2.01.22	Safe Hold Mode
2.01.23	Automated Switchover Notification
2.01.24	Hazard Command Operations

Item Number	LaRC-Specific Engineering Best Practices
3.00	Contamination Control (CC)
3.01	CC – General
3.01.01	Laser Contamination Control Plan
3.01.02	Contamination Control Requirements and Processes
3.01.03	Fastener Lubrication in Contamination Sensitive Hardware
4.00	Electronic Systems (ES)
4.01	ES – Computer
4.01.01	Flight System Restart
4.01.02	Computing Parameters
4.02	ES - EEE Parts
4.02.01	EEE Parts Program
4.02.02	Grade-One Parts Vs. COTS
4.02.03	Parts Derating
4.03	ES – General
4.03.01	Static Bleed Path
4.03.02	Shielding
4.03.03	Back EMF Suppression
4.03.04	Shorts Avoidance
4.03.05	Cable Cut Preparation

Item Number	LaRC-Specific Engineering Best Practices
4.03.06	Non-Critical Circuit Design
4.03.07	Current Limiting Architecture Design
4.03.08	Transient Effects Avoidance
4.03.09	Synchronous Design
4.03.12	Avoidance of Inadvertent Operation
4.03.13	Isolation Between Redundant Components
4.03.14	Power-On Time
4.03.15	PCB Testing
4.03.16	Corona Effects Avoidance
4.03.18	RDM Level
4.03.19	EMI Minimization
4.03.20	Safe To Mate Verification
4.03.22	Parts Failures Analysis
4.03.23	Flight Hardware Interface Protection
4.03.24	Ungrounded Conductive Material
4.03.25	Test Points and Plugs
4.03.26	I/O and Power Circuit Margin
4.03.27	Parts List Review
4.03.28	Prohibited Materials for Electrical Hardware
4.03.29	RF Component Testing for Multipaction and Corona

Item Number	LaRC-Specific Engineering Best Practices
4.04	ES – Interfaces
4.04.02	External Connectors
4.04.03	Use of Common Electrical Interfaces
4.04.05	Use of Reliable Interfaces
4.04.06	Flight Connectors Mating
4.04.07	Electrical Interface Verification
4.05	ES – Grounding
4.05.01	Circuit Return Path
4.05.02	DC Ground
4.05.03	Grounding Concept Design -
4.06	ES – Power
4.06.01	Critical/ Non-Critical Load Selection
4.06.03	Power System Grounding/Fault Tolerance
4.06.04	Surge Control/ Load Removal
4.06.05	Power Margin
4.07	ES – Telemetry
4.07.02	Real-Time Telemetry During Mission Critical Events
4.07.03	Downlink Data Quality
4.07.04	Simultaneous Command/telemetry Capability
4.07.05	Information System Capability

Item Number	LaRC-Specific Engineering Best Practices
4.07.06	Early Determination of S/C State
4.07.09	On-board Recording Capacity
4.07.10	Link Margins
5.00	Fluids
5.01	Fluids – General
5.01.01	Positive Protection From Interchangeability of Fluid Service Lines
5.01.02	Ground Service Points for Fluid Systems
5.01.03	Separation Provision for Fluid Systems
5.01.04	Temperature And Pressure Monitoring Requirements For Potentially Hazardous Reactive Fluids
5.01.05	Capping Of Fluid Servicing And Test Ports not Required to Function in Flight
5.01.06	Fluid Systems Components Whose Function Is Dependent On Direction Of Flow - Protection Against Incorrect Installation
5.01.07	Verification Test Provisions for Fluid Supplies
5.01.08	Protection of Pressurized Systems from Damage Due to Pressuring Depletion - Support Equipment
5.01.09	Fluid Line Routing And Installation
5.01.10	Cleanliness Of Flowing Fluids And Associated Systems
5.01.11	Standardization Of Functional Testing of Pressure Relief Valves
5.01.12	Cleanliness Protection For Fluid Systems
5.01.13	Fluid Systems Cleanliness
5.01.14	Dew Point Requirement for Purge Gases

Item Number	LaRC-Specific Engineering Best Practices
5.01.15	Design For Flushing and Draining of Fluid Systems
5.01.16	Verification of Contents of Liquid or Gas Containers
5.01.17	Filter Protection Of Sensitive Fluid Components
5.01.18	Pressure Relief For Pressure Vessels/Systems
5.01.19	Spacecraft Venting-Induced Perturbing Forces
5.01.20	Nozzles And Vents - Protection Prior To Launch
5.01.21	Separation of Hypergolic Reactants
5.01.22	Propellant Sampling in Liquid Propulsion Systems
6.00	Guidance, Navigation and Control (GN&C)
6.01	GN&C – General
6.01.01	Flight Control System Stability Margins
6.01.02	Flight Control System Global Stability Analysis
6.01.03	Flight Control System Actuator Size
6.01.04	GN&C Device Testing
6.01.05	Gyroscopes - Verification of Operational Status
7.00	Mechanical Systems (MS)
7.01	MS - Mass
7.01.01	Mass Allocation Methodology
7.01.02	Mass/Propellant Margins

Item Number	LaRC-Specific Engineering Best Practices
7.01.03	Mass Properties Variability
7.02	MS – Structures
7.02.01	Mechanical Clearance Analysis
7.02.02	Integrated Design Interactions
7.02.03	Use of Positive Location System
7.02.04	Static load Testing
7.02.05	Avoidance of Sensor & Antenna Blockage
7.02.06	Field of View Clearance
7.02.09	Fasteners
7.03	MS – Thermal
7.03.01	Thermal Test Limits
7.03.02	Thermal Balance Test
7.03.03	Thermal Vacuum Testing for Systems and Components in Unpressurized Areas
7.03.04	Thermal Control for Propellant Interaction
7.03.05	Thermal Design Margin
7.03.06	Thermal Coatings Properties for Analysis
8.00	Operations (OP)
8.01	OP – Design
8.01.01	Minimization of Uplink and Downlink Transfers

Item Number	LaRC-Specific Engineering Best Practices
8.01.02	Flight Systems and Flight Operations Concurrent Design
8.01.03	Operational Complexity Minimization
8.02	OP – Test
8.02.01	Mission Preparation Tests
8.02.02	Ground Based Testing During Flight Operations
8.02.03	Validation Through Operational Readiness Testing
8.02.04	Protecting Flight Equipment from Support Equipment
8.03	OP – Rules
8.03.01	Flight Sequence Testing
8.03.02	Launch and Mission Critical Sequences
8.03.03	Early Demonstration of Functional Capabilities
8.03.04	Mission Time-Critical Operations
8.03.05	Critical Event Contingency Plans
8.03.06	Launch Sequence Design
8.03.07	System Developers Involvement in Operations
8.03.08	Receiver-Off Command Inhibit
8.03.09	Mission-Critical Event Coverage
8.03.10	Flight Rules Constraints on Flight Sequences
8.03.11	Avoidance of Power Cycling
8.03.12	Flight S/W Loads Verification

Item Number	LaRC-Specific Engineering Best Practices
8.04	OP – Training
8.04.01	Train As You Fly
8.04.02	Capture Knowledge and Lessons Learned
9.00	Reliability (Rel)
9.01	Rel - Fault and Failure Protection
9.01.01	Fault Protection During Critical Mission Activities
9.01.02	Fault Protection for Non-Critical Periods
9.01.03	Fault Protection Commandability
9.01.04	Fault Protection Sensitivity
9.01.05	Co-Located Element Failure Effects Avoidance
9.01.06	Fault Tolerance for Space Systems
9.01.07	Non-Essential Circuitry Faults
9.01.08	Avoidance of Loss of Mission Due to Single Failure
9.01.09	Single-point Failure Risk Management
9.01.10	Fault Protection Testing
9.02	Rel – Redundancy
9.02.01	Redundant Systems Independence
9.02.02	Single-point Failures in Redundant Processing Strings

Item Number	LaRC-Specific Engineering Best Practices
10.00	Software (SW)
10.01	SW – General
10.01.01	S/W Design for Test
10.01.02	S/W Support of Computer Resources Measurements
10.01.03	S/W Support of Fault Protection
10.01.04	Software Logic Design
10.01.05	S/W Input/output Data Design
10.01.06	Detection of Data Faults
10.01.07	S/W Modification Protection
10.01.08	S/W Resource Over-usage Accommodation
10.01.09	S/W Processing Failure Accommodation
10.01.10	S/W Memory Protection
10.01.11	S/W Interrupt Tolerance
10.01.12	S/W Deadlock Avoidance
10.01.13	Code/Software Updating
10.01.14	Dead S/W Code Avoidance
10.01.15	FSW Long Duration Testing
10.01.16	FSW Regression Testing

Item Number	LaRC-Specific Engineering Best Practices
11.00	System - (Sys)
11.01	Sys – General
11.01.01	Use of Lessons Learned
11.01.02	Design Robustness Considerations
11.01.03	System Design Verification Plan
11.01.04	Spare Units Plan
11.01.05	Polarity, Orientation, Position Verification
11.01.06	Statistical Analysis Approach Definition
11.01.07	Thruster Plume, Venting Analysis
11.01.08	Stray-light Input Analysis
11.01.09	Closeout Photo Documentation of Key Assemblies
11.01.10	Development and Maintenance of Mission Critical Components
11.01.11	Qualification of Heritage Hardware

G.9. LaRC-Specific Engineering Best Practices Database

The details of the Best Practices identified in this Appendix are contained in a searchable database. The user can pull out those practices that are of most interest by searching on the technical area of interest. The database is captured in LF209 and can be found at the following hyperlink: <https://nef.nasa.gov/forms/1598783639>.